

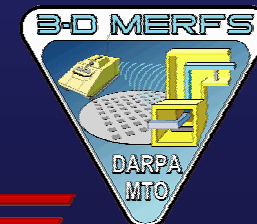
Powering the Integrated Microsystem

John. D. Evans, Ph.D., MBA

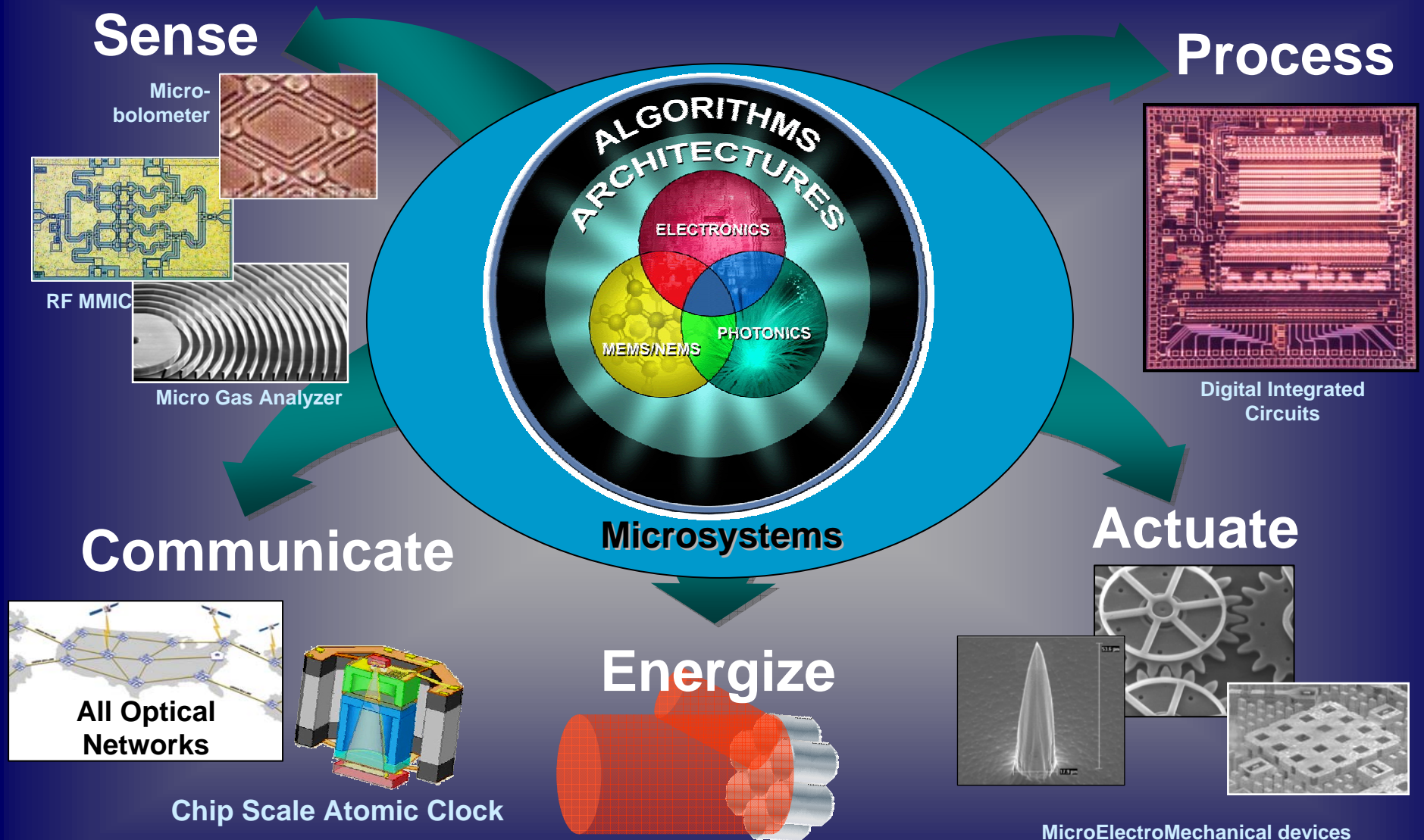
March 7, 2007

San Jose, CA

Program	Goal
3-D MERFS	Enable dramatic reduction in size (30x) and cost (100x) for MMW systems by demonstrating a new air-core-coax "printed circuit board" technology for MMW.
Analog Spectral Processors	Enable dramatic decreases in radio size and power by simultaneously trading advances in new radio architectures and new MEMS filters.
Disruptive Manufacturing Technologies	Exploit opportunities to dramatically decrease manufacturing costs for existing military systems.
Micro Electric (Space) Propulsion	Demonstrate thrusters with wide Isp dynamic range, enabling spacecraft to flexibly respond to changing national needs.
Micro Isotope Power Sources	Demonstrate high-energy-density isotope batteries.



The Integrated Microsystem



Power vs. Scale for Autonomous Units

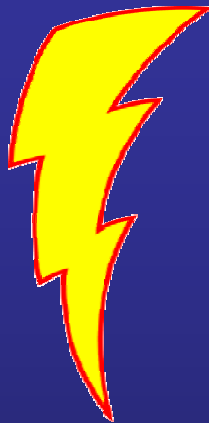
~200 MegaWatts
<0.1% power

10-100 kW
2% power

1-10 kW
2% power

1-10 W
10% power

W - nW
>50% power



Aircraft Carrier



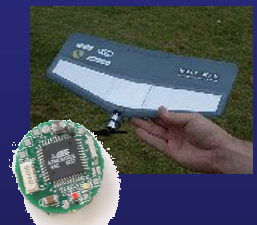
Unit



Vehicle



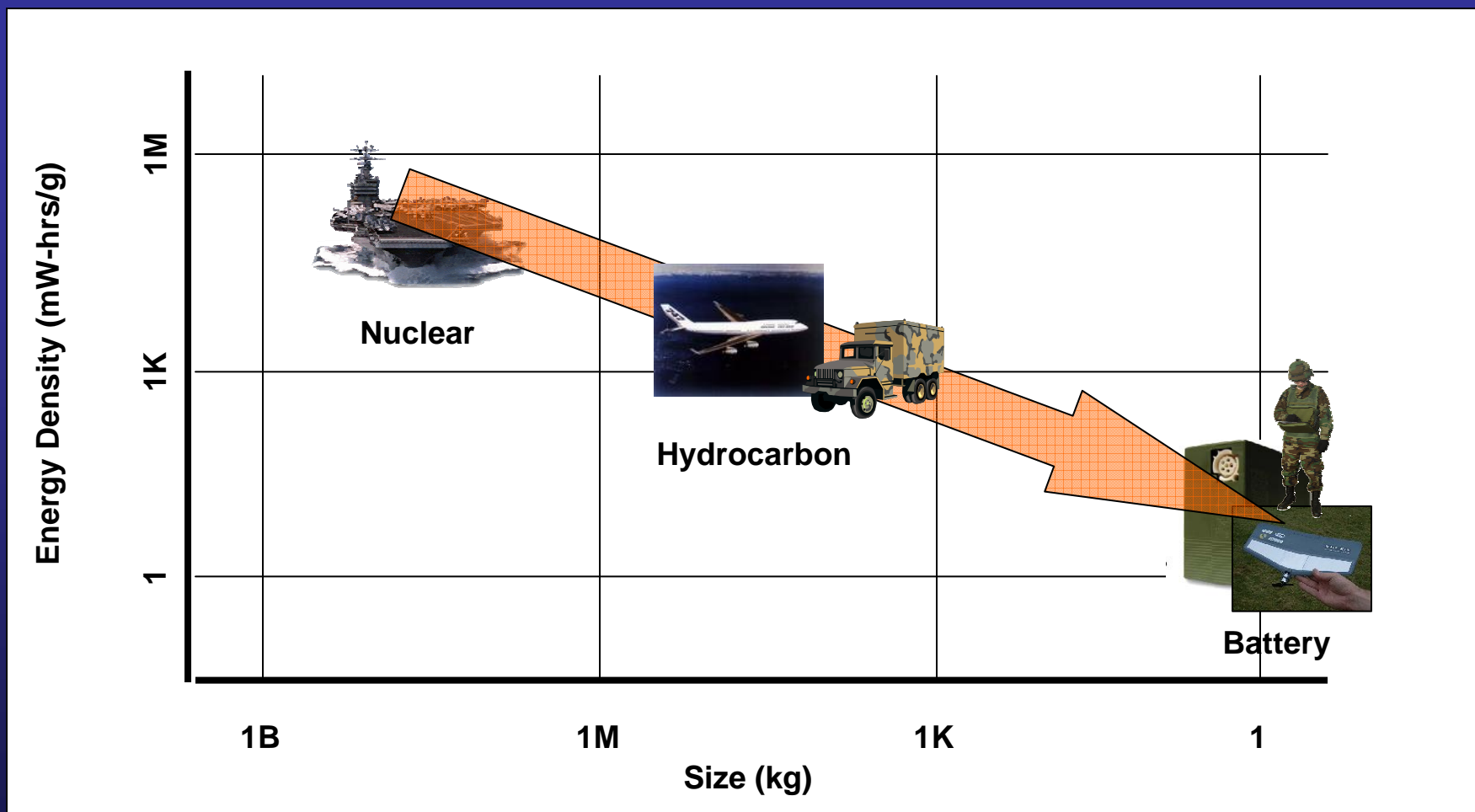
Soldier



Sensor
 μ UAV

Increased projection of U.S. Interests and Capability →

Power Density vs. Size



We have yet to effectively scale power systems to small size

Two approaches

Exploit scaling laws to
use less power



Many system-specific
opportunities

Scale macro
power systems



Really hard

Use Less Power



Analog Spectral Processors

Dramatic decrease in radio power by off-loading RF signal processing to passive MEMS filter arrays.



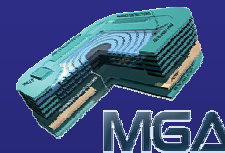
Chip Scale Atomic Clock

300X reduction in power consumption (from 10 W to <30 mW) for atomic clocks through system miniaturization.



Energy Starved Electronics

Demonstrate 100X improvement in energy per operation over conventional electronics through sub threshold operation.



Micro-Gas Analyzers

10,000x decrease in power required per analysis through system miniaturization.



Super High Efficiency Diode Sources

80% electrical-to-optical efficiency from semiconductor diode laser bars (880nm to 980nm)



Micro Electric (Space) Propulsion

Doubling of electrical efficiency for electric propulsion systems through miniaturization.

Scale Macro Power Systems



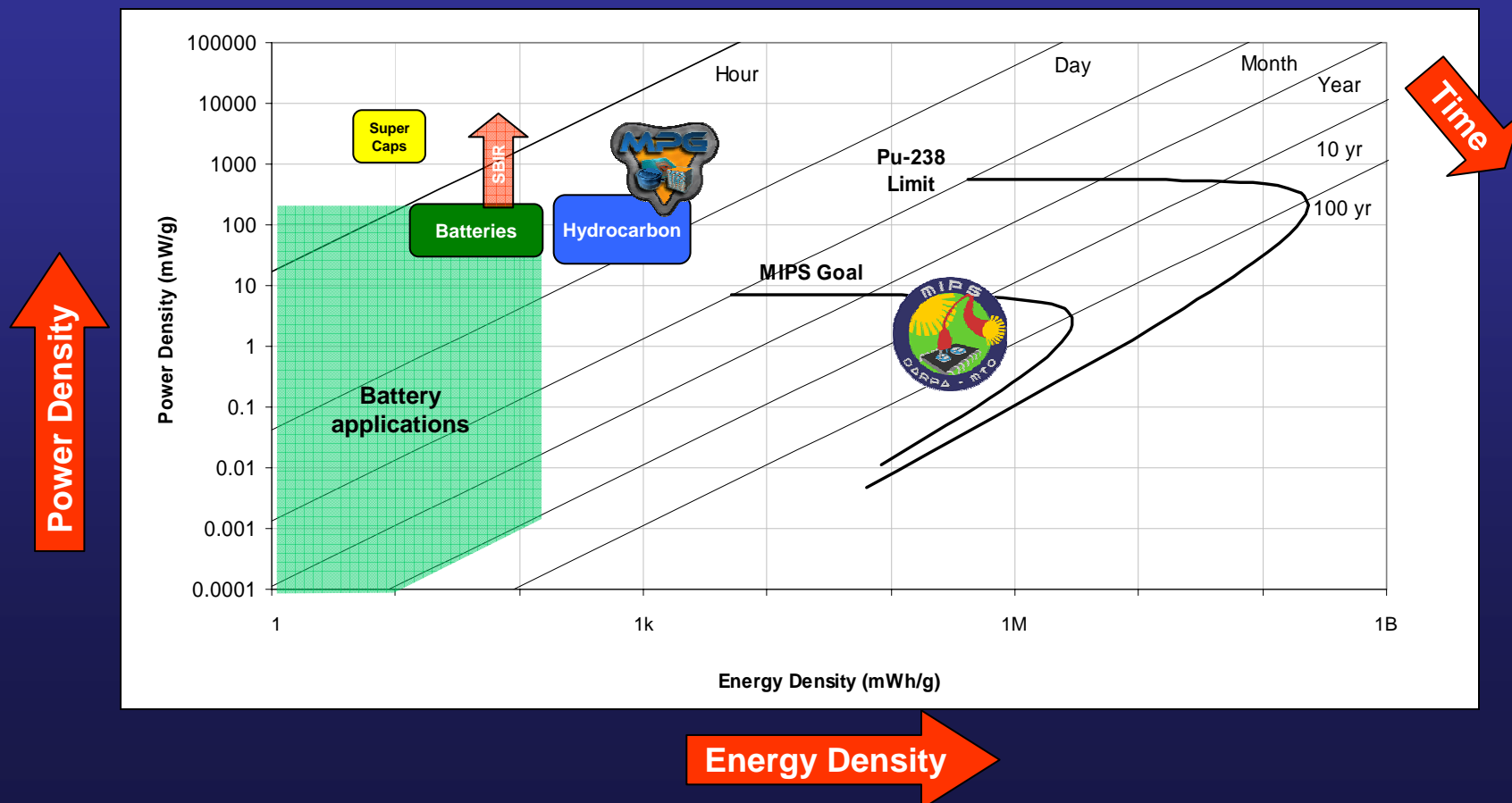
Micro Isotope Power Sources

Small power sources based on energy conversion from isotopes.

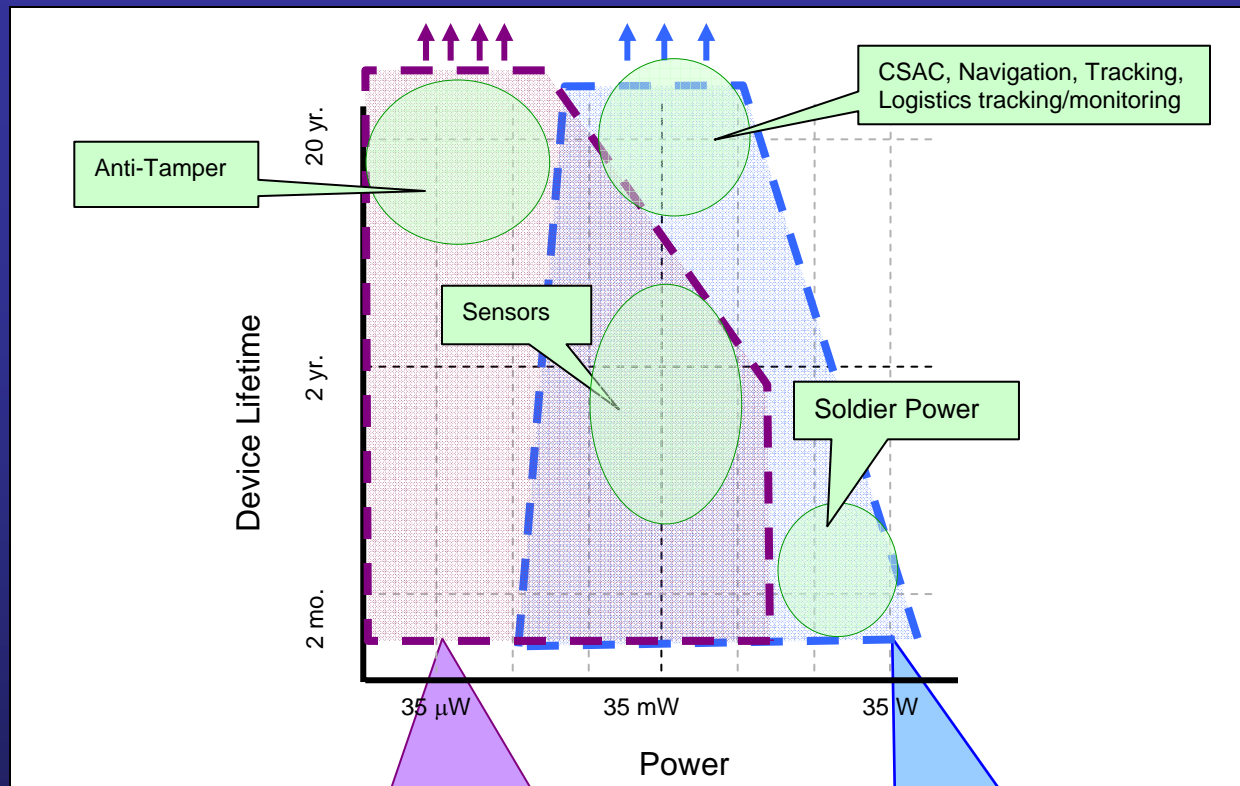


Micro Power Generation

Micro-scale power generation from hydrocarbon fuel



Micro Isotope Power Sources



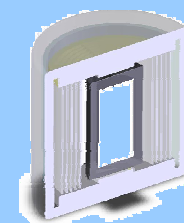
Area-based Approaches (beta, alpha)



Isotope α / β source
Particle \rightarrow electrical converter

Volumetric Approaches

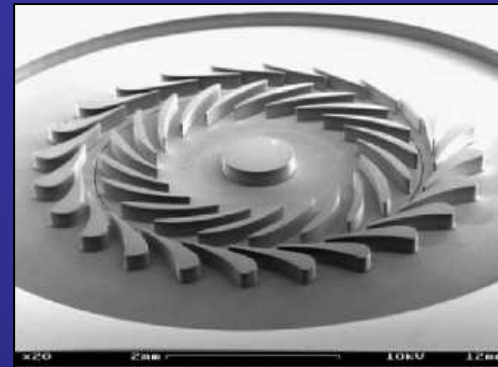
E.g. Sandia Thermo-Photo Voltaic



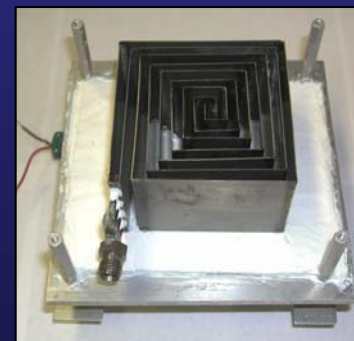
Micro-Hydrocarbon Conversion Challenging

Many attempts....

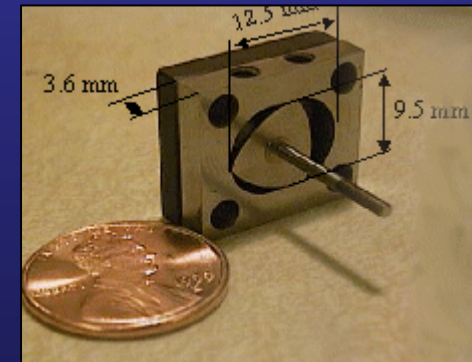
...most have run into
significant technical
challenges as they move
to micro-scale.



MIT Micro-Turbine



USC Swiss-Roll counter-flow
heat exchanger

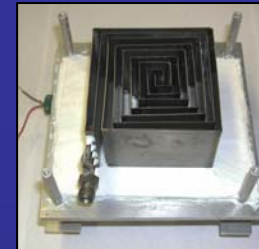


Berkeley Micro-Wankel

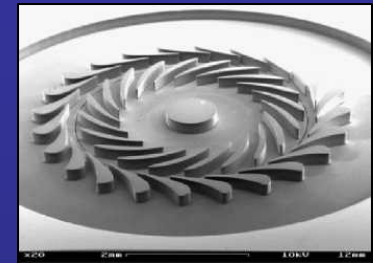
Micro-Hydrocarbon Conversion Challenging

Some challenges

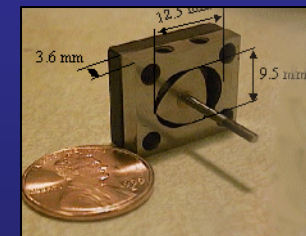
- As you miniaturize, surface-area-to-volume increases. Drives inefficiencies...
 - Thermal losses (quenching)
 - Friction (bearings)
 - Viscous losses in liquid flow
- Poor mixing on micro-scale
 - Low Reynolds numbers poses limits on use of turbulence
 - Diffusion insufficient
 - Chaotic mixing limited by 2-D nature of micro-fabricated systems.



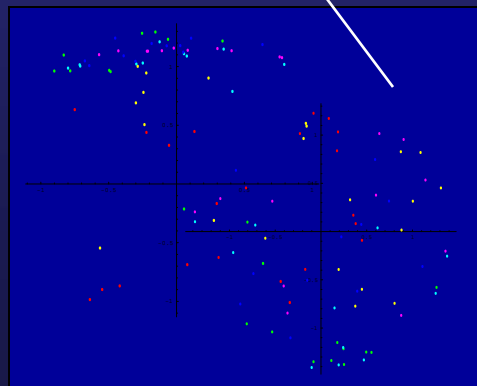
USC Swiss-Roll counter-flow heat exchanger



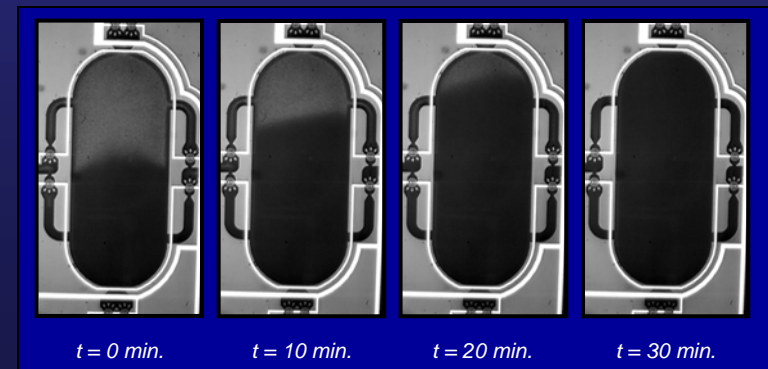
MIT Micro-Turbine



Berkeley Micro-Wankel

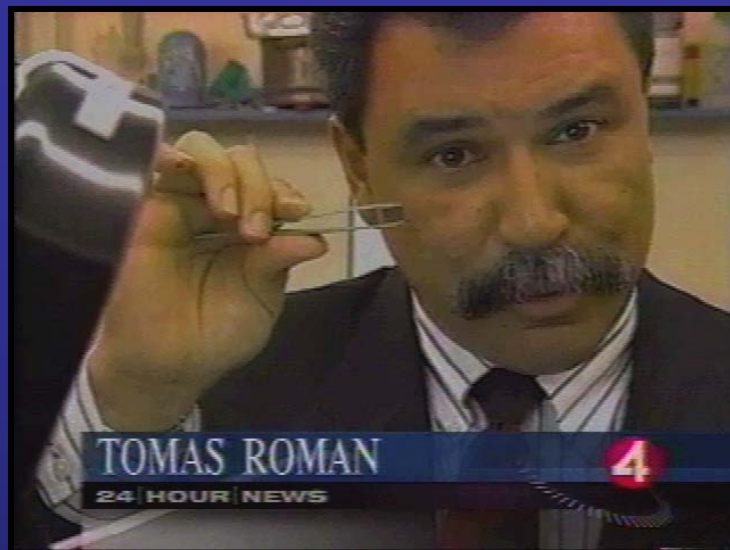


J. Evans, Poincare maps for perturbed quadra-pole mixer

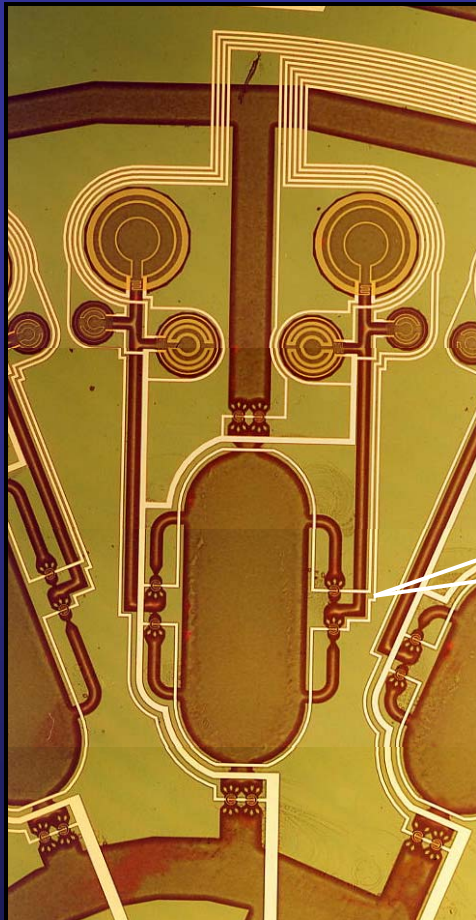


J. Evans, 82 nl, 100 μm x 600 μm x 1500 μm

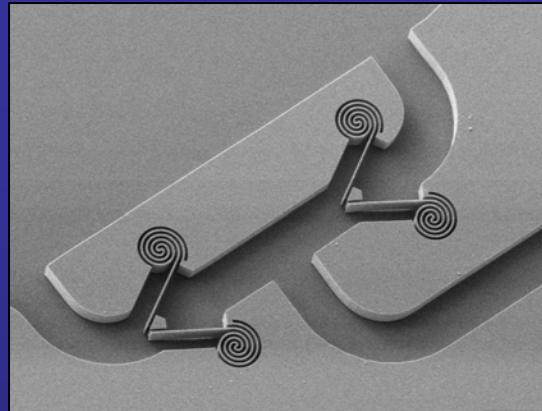
The Challenge of Microfluidics...



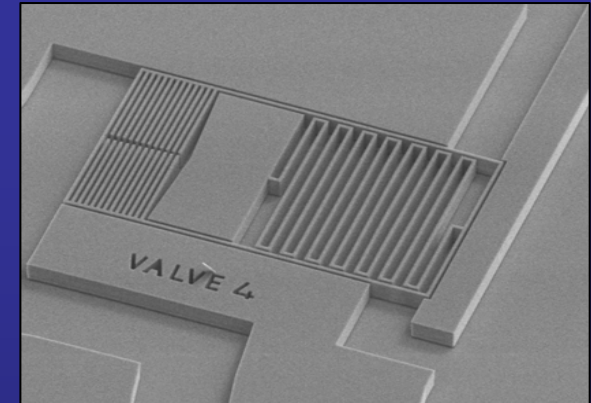
Microfluidics Limited by Geometric & Materials Constraints



J. Evans, Quadra-Pole mixer



J. Evans, Spring valves



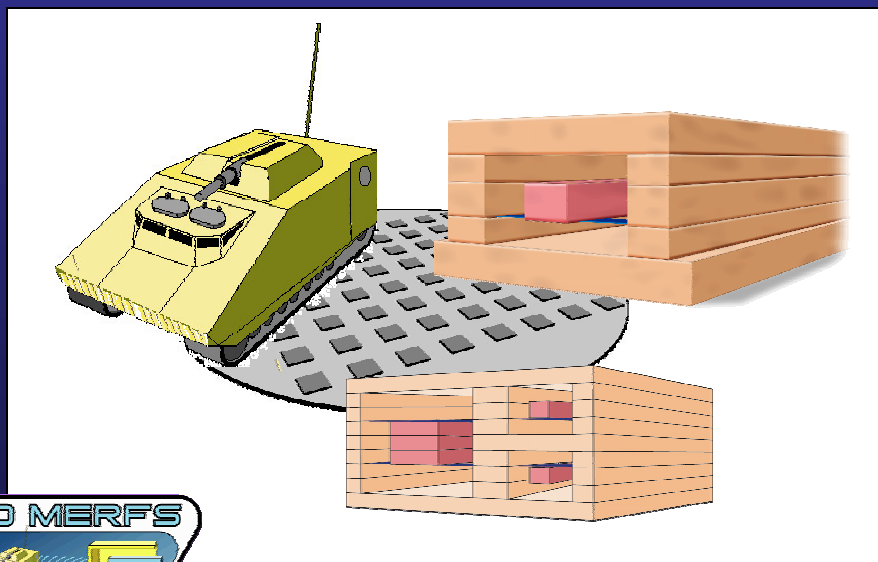
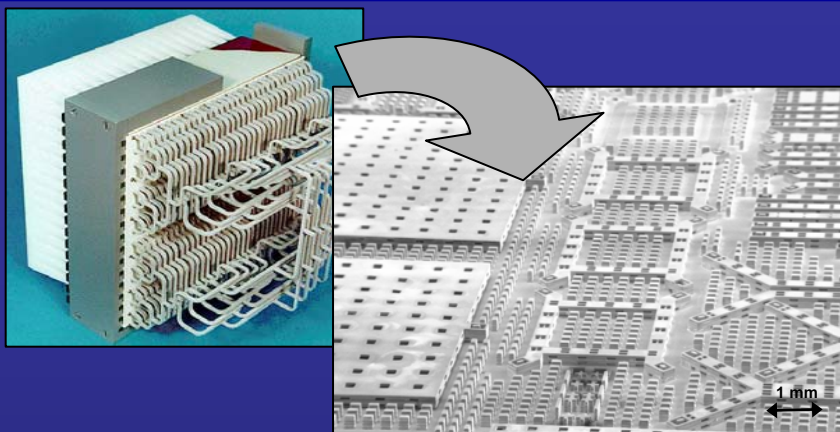
J. Evans, 'BSaC' Valve

Valves (pumps, regulators, etc.) typically require

- Precision fabrication in at least two orthogonal planes
- Multiple material properties for structure, seal, etc.

3-D MERFS

John D. Evans



Goal:

Demonstrate an affordable, high performance 3-D "Printed Circuit Board" technology for RF/MMW based upon air-core Recta-coax.

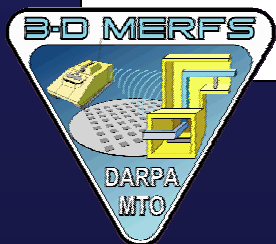
Technical Challenges

Phase I:

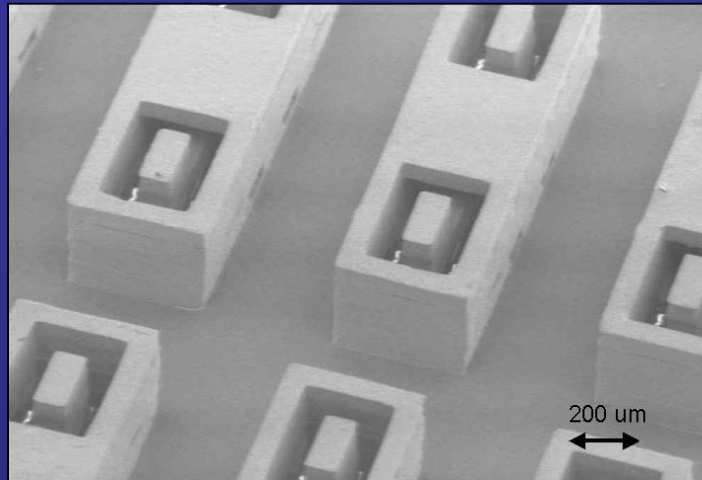
- Precision 3-D fabrication using new material system that utilizes air (sacrificial material), copper, and structural polymer.
- Demonstration of new *sacrificial* high-aspect-ratio photo resist.
- Demonstration of new metal/polymer/copper CMP process.

Phase II:

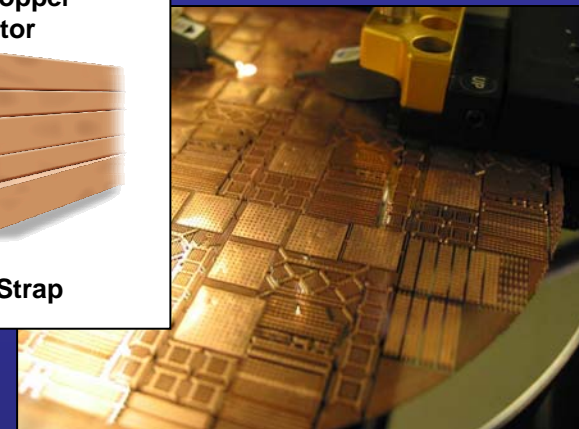
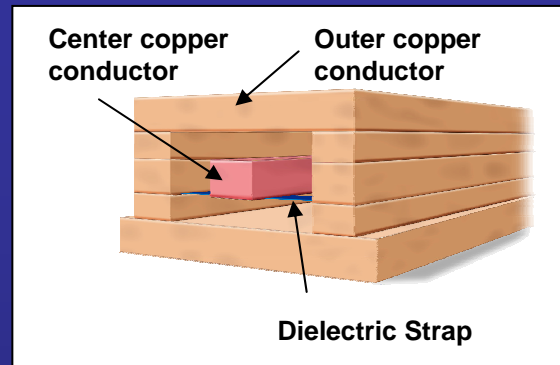
- Double number of lithographic layers (5 \rightarrow 9) , thereby enable crossovers and doubling RF performance.
- Balance layer adhesion vs. CMP shear stress.
- Improve fabrication yield.



Images of 3-D MERFS Structures (5 lithographic layers, 3 Material)



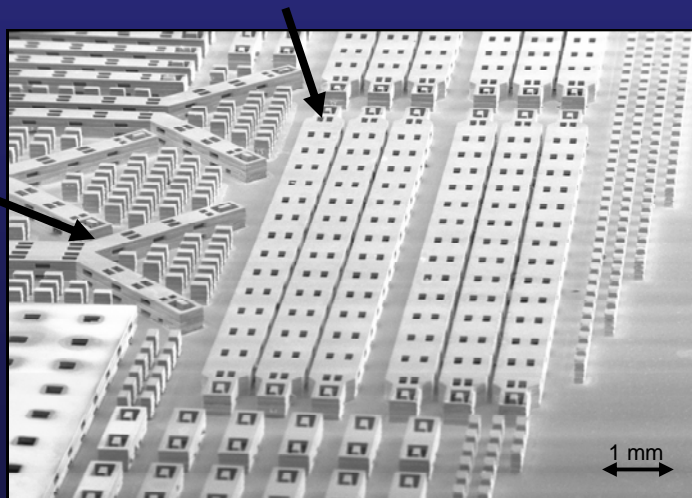
"Launch" De-imbedding Test Structures



6-Inch 3-D MERFS Wafer on RF Probe Station

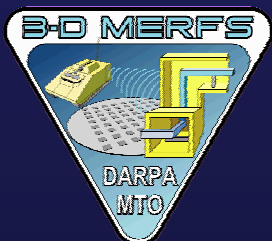
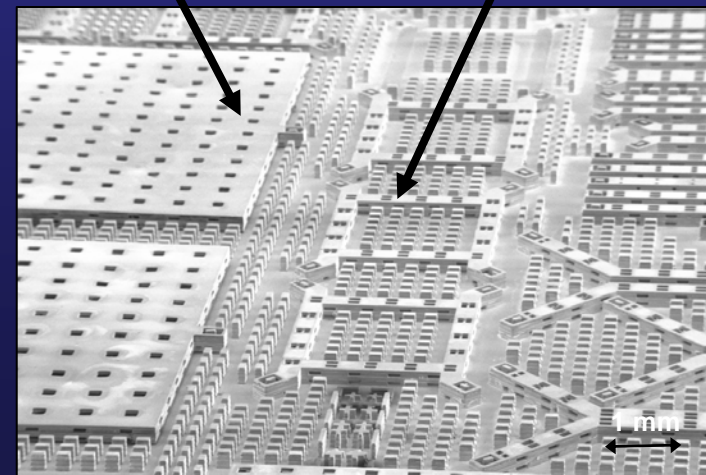
Isolation test structures

Attenuation Test Structure

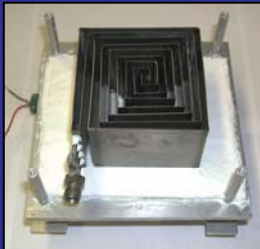


Cavity Resonator

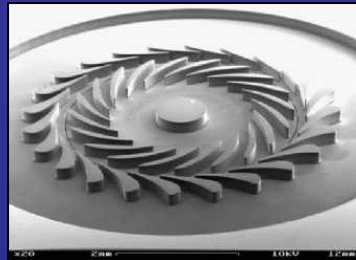
Hybrid Coupler



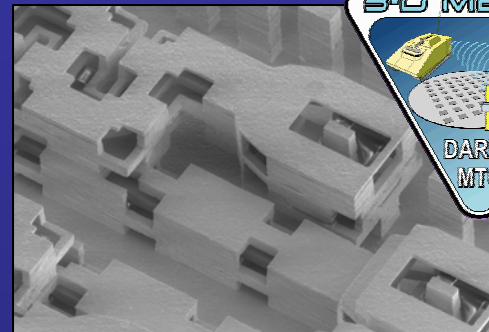
Maybe its time for a new push...



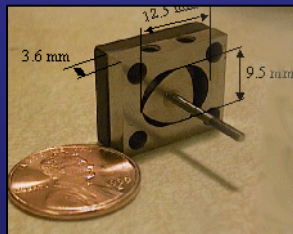
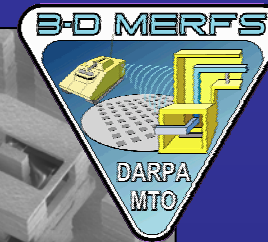
USC Swiss-Roll counter-flow
heat exchanger



MIT Micro-Turbine



New Polyrata™ Fabrication Technology
Enables complex 3-D MEMS Geometries



Berkeley Micro-Wankel

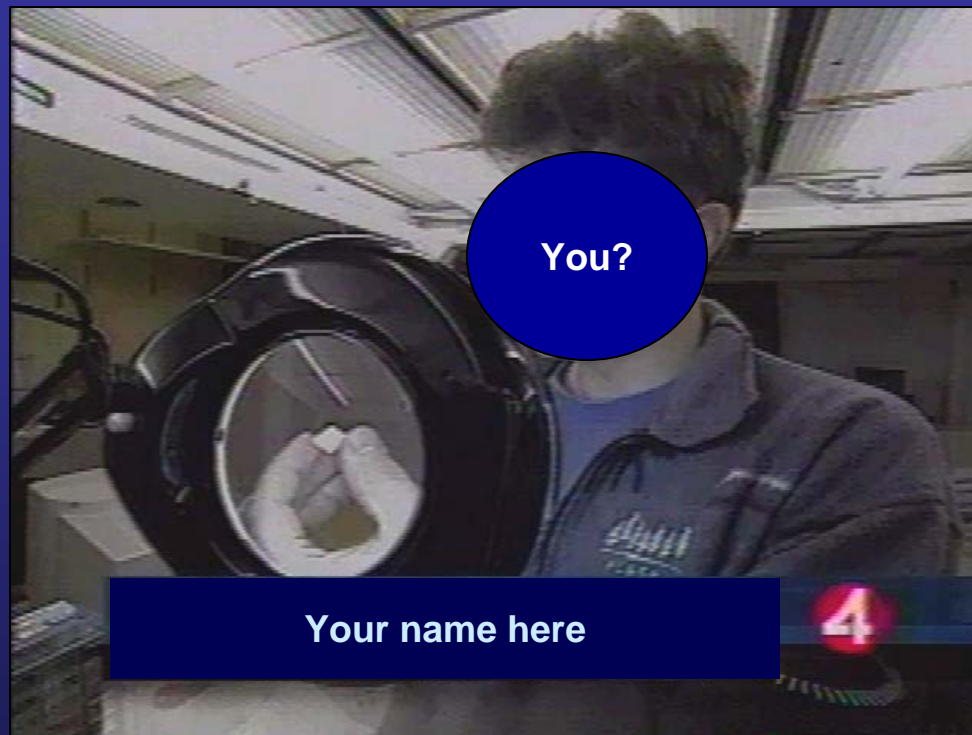
**Critical mass
of new ideas?**

**Who's the next
Power PM?**



CalTech Micro-Solid
Oxide Fuel Cell

Maybe it's you...



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